

# CDIO Projects in DTU's Chemical and Biochemical B.Eng. Study Program

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## ABSTRACT

The aim of this paper is to describe how the CDIO standards [1] have influenced the cross-disciplinary projects that are part of the study plan for the Chemical and Biochemical B.Eng. program. Four projects are described: The 1<sup>st</sup> semester design-build project on cleaning of waste water from a power plant, the 2<sup>nd</sup> semester laboratory project concerning antimicrobial resistant *E. coli* bacteria in retail meats, the 3<sup>rd</sup> semester project on unit operations in enzyme production, the 4<sup>th</sup> semester project on the fermentation and purification part of enzyme production.

## KEYWORDS

Design-build projects, CDIO-based study programs, chemical engineering projects.

## INTRODUCTION

As of September 2008 DTU (The Technical University of Denmark) decided to start implementing the CDIO learning concept in seven of the B.Eng. study programs, including the study program in Chemical and Biochemical Engineering. Vigild et al [2] have described the initial process of adapting the CDIO standards to the program and a number of course adoptions are described in [3] and [9].

Other schools are in the process of adopting (or have adopted) the CDIO standards for their chemical engineering programs; Cheah [4] describes the process for the Singapore Polytechnic program with course details presented in [5] and [8].

However, when it comes to design-build and other cross-disciplinary experimental projects very few descriptions are published. Huiting et al [6] describes a water-sanitation design-build project which is part of the chemical engineering program at Singapore Polytechnic.

## The B. Eng. Chemical Engineering Program at DTU

The program is a 7 semester (3½ year) program with 1 semester of engineering practice included. The study plan is shown in table 1.

Admission is September and February with a total yearly enrollment of about 60-70 students. All compulsory courses are given twice a year.

As is evident from table 1, the program is made up of a number of separate courses with 4-6 courses taught in parallel each semester. This is mainly due to the requirement that the program should fit into the overall structure of teaching at DTU which is modular by design and primarily aimed at supporting flexible programs with a high percentage of elective courses and to a lesser extent geared towards programs like the present where a high degree of course interaction is desired.

However, since there are no electives during the first 4 semesters, it is not difficult to have cross-disciplinary projects integrated in the curriculum but the challenge is to accommodate students that - for some reason or another - take the courses in a different (slower) pace than outlined by the plan. This is not unusual; less than 20% of the students finish their studies in 3½ years.

At DTU we decided to have cross-disciplinary projects on the first four semesters, two of them being design-build projects. These are placed on the first and the fourth semester.

Table 1

### Study plan for the Chemical and Biochemical B.Eng. program at DTU

Each row describes one semester. Shading indicates courses collaborating on the projects.

Course load is measured in ECTS (European Credit Transfer System) credits.

One academic year corresponds to 60 ECTS-credits, equivalent to appr. 1700 hours of study.

Semester period (13 weeks)											Lab period (3 weeks)
	2.5 ECTS	2.5 ECTS	2.5 ECTS	2.5 ECTS	2.5 ECTS	2.5 ECTS	2.5 ECTS	2.5 ECTS	2.5 ECTS	2.5 ECTS	5 ECTS
1	Math 1		Inorg. Analysis (Lab)	Inorganic Chemistry	Physics			General Chemistry		Chemical & Biochemical Process Engineering	
2	Math 2		Physical Chemistry		Biological Chemistry			Organic Chemistry		Analytical Chemistry (Lab)	
3	Organic Synthesis, Lab Course		Chem. Engineering Thermodynamics		Mathematical Models for Chemical & Biochemical Systems			Unit Operations of Chemical Engineering			
4	Statistics			Materials Science			Biotechnology & Process Design				
5	Engineering Practice										
6	Process Control		Reaction Engineering		Process Design		Elective courses				
7	Elective courses				B.Eng. Thesis project						

## THE PROJECTS

**The 1<sup>st</sup> semester design—build project** has a coal fired power plant or a waste incinerating facility as the overall frame. The students calculate inlet air flow rate and flue gas composition as well as the production of power and district heating. This is done in the course 'Chemical & Biochemical Process Engineering'. In the physics course, they do sizing calculations on the electrostatic filter that removes the fly ash.

The 'design-build' part of the project has some inherent constraints since first year students are not skilled in all aspects of laboratory work. Thus, in the 'build' phase we restrict ourselves to consider simple techniques that students know from their first semester lab course on qualitative analysis.

This part of the project is done in the general chemistry course and focuses on removing heavy metals from the waste water of the power plant. The students are asked to suggest a couple of methods for removing a specific heavy metal from the waste water. For each method the cost, the effectiveness and environmental aspects should be estimated. Finally, the most promising one is described in detail, tested in the lab and documented in a report.

Thus, the three courses participating have the frame in common, but investigate different aspects of power production.

This project trains several of the skills from CDIO Syllabus category 2 (Engineering reasoning and problem solving, experimentation and knowledge discovery, personal skills and attitudes) and category 3 (teamwork, communication) and 4 as well (e.g. the impact of engineering on society, Society's Regulation of Engineering, the design process, utilization of knowledge in design).

**The 2<sup>nd</sup> semester project** is a practical/theoretical project concerning antimicrobial resistant *E. coli* bacteria in retail meats. The students are working in groups and each group is responsible for a subtopic (Sample information, *E. coli* tetracycline resistance, multi-drug resistance, resistance gene detection or horizontal gene transfer).

All groups collect two meat samples in retail stores based on criteria the class defines. The samples are used to perform the same set of experiments in all groups. The groups share their results between groups based on topic meaning that the groups do not present their own results but the results related to their topic on behalf of the entire class.

The students gain practical and theoretic knowledge on the overall topic and more in depth knowledge on their subtopic. They train study design skills, technical communication, raw data handling, data presentation, multi-disciplinary collaboration, data interpretation and presentation.

Thus, the project trains a number of skills from CDIO Syllabus category 2 (Engineering reasoning and problem solving, experimentation and knowledge discovery, personal skills and attitudes), category 3 (teamwork, communication) and 4 as well (e.g. roles and responsibility of engineers, the impact of engineering on society, society's regulation of engineering).

**The 3<sup>rd</sup> semester project** focuses on certain aspects of enzyme production. The project is cross-disciplinary and theoretical with no lab activity involved. Three courses participate: In

the mathematical modeling course students design heat exchangers from the fundamental transport and energy balance equations, in the thermodynamics course a refrigeration unit for broth cooling is designed, in the unit operations course the students design a cooling tower that will supply the cooling water used by the refrigerator, and they design drum filters and centrifuges for broth purification.

A visit to an enzyme producing company is part of the course thus the students see real cooling towers, drum filters etc and realize that their design is quite realistic.

Students work in groups of 4-5 persons and present their findings in the form of reports. This project trains a number of skills from the CDIO Syllabus (e.g. Engineering reasoning and problem solving, personal skills and attitudes, teamwork, written communication, Multidisciplinary Design).

**The 4<sup>th</sup> semester design-build project** on biotechnology also has enzyme production as the main theme. Here the strain selection, fermentation and purification steps are in focus. The time allotted is 3 weeks full time for the 'build' part with the 'design' part taking place in the preceding period.

The fermentation lab is GMO-approved, but the pilot plant facilities where the purification takes place are not; therefore the strain selection is limited to non-GMO organisms.

Given the problem (this semester: Production of cellulolytic enzymes in the fungus *Trichoderma reesei*), the students select suitable substrates. Then they plan and perform fermentation experiments in 5 L lab fermentors. Experiments to aid designing a downstream recovery process are performed. Using pilot scale equipment, where larger volumes are required, 3-4 groups pool their fermented broths and design and perform the product recovery. Finally, they design the process in large scale. The groups hand in reports and make oral presentations of their findings.

This project trains several of the skills from CDIO Syllabus category 2 (engineering reasoning and problem solving, experimentation and knowledge discovery, personal skills and attitudes) and category 3 (teamwork, communication) and 4 as well (e.g. society's regulation of engineering, setting system goals and requirements, the design process, utilization of knowledge in design, designing the implementation process).

## DISCUSSION AND CONCLUSION

Most of our students follow the prescribed course plan. However, a number of students do not. E.g. this semester, about 75% of the students taking the 3<sup>rd</sup> semester course on unit operations take the thermodynamics course as well – but 25% do not follow both courses. Therefore, the 3<sup>rd</sup> semester cross-disciplinary project is divided into separate assignments and each course evaluates its own part. The same goes (to a lesser extent) for the 1<sup>st</sup> semester project.

The students that enrolled in September 2008 are now in their 6<sup>th</sup> semester, thus, the first students exposed to the CDIO principles have completed their first 4 semesters of compulsory courses and have at the time of writing (spring 2011) just finished their 5<sup>th</sup> semester practical training. Thus, the 4<sup>th</sup> semester project has run twice, the 1<sup>st</sup> semester project 5 times.

In accordance with the CDIO concept, three of the four projects have significant experimental parts. This is a very positive experience, but also a limiting factor especially in the 'design' phase of the 1<sup>st</sup> and 4<sup>th</sup> semester design-build projects. They are not quite as open-ended as we would like them to be; this is mostly a question of lab facilities, but the limited time allotted to the projects and lack of student lab experience also make open-ended problem formulations difficult.

Two of the projects include company visits; this is - for several reasons - very much appreciated by the students; it helps them putting their project into an engineering context, to visualize the engineering way of thinking and to realize that environmental issues are of great concern to the chemical and biochemical industries.

Based on the feedback from student evaluations and the teaching experience we are in an ongoing process of improving the projects, also aiming to use more up-to-date equipment and giving more realistic problems to the students.

### References:

- [1] The CDIO Standards. CDIO Initiative, [www.cdio.org](http://www.cdio.org)
- [2] Vigild M.E, May M. and Clement K, "CDIO in Chemical Engineering Education", Proceedings of the 3rd International CDIO Conference, MIT, Cambridge, Massachusetts, June 11-14, 2007
- [3] Vigild M.E. and Kiil S, "Changing Learning Methods of Chemical Engineering – CDIO and Chemical Product Engineering", Proceedings of the 4th International CDIO Conference, Hoogeschool Gent, Gent, Belgium, June 16-19, 2008
- [4] Cheah Sin-Moh, "Using CDIO to Revamp the Chemical Engineering Curriculum", Proceedings of the 5th International CDIO Conference, Singapore Polytechnic, Singapore, June 7 - 10, 2009
- [5] Yang K.Y.E. and Cheah S., "Designing Active Learning Experiences for a First-Year Introduction to Chemical Engineering Module: Lessons Learnt", Proceedings of the 5th International CDIO Conference, Singapore Polytechnic, Singapore, June 7 - 10, 2009
- [6] Huiting C, Sale D and Yeo A, "CDIO as a force for good – a Water Sanitation and Hygiene Community Service Project in Myanmar", Proceedings of the 6th International CDIO Conference, École Polytechnique, Montréal, June 15-18, 2010
- [7] Koh C, "Promoting Systems Thinking and Problem Solving Skills through Active Learning". Proceedings of the 6th International CDIO Conference, École Polytechnique, Montréal, June 15-18, 2010
- [8] Ting Kok-Eng and Chrah S, "Assessment of CDIO skills for Student Final Year (Capstone) Project of Different Genres", Proceedings of the 6th International CDIO Conference, École Polytechnique, Montréal, June 15-18, 2010
- [9] von Solms N, Woodley J, Johnsson J.E, Abildskov J, "Integrating Chemical Engineering Fundamentals in the Capstone Process Design Project", Proceedings of the 6th International CDIO Conference, École Polytechnique, Montréal, June 15-18, 2010

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